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BOTANY REFERENCE NOTES

Paper – I

Plant Resource Development - I

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Plant Resource Development

Prescribed syllabus

Domestication and introduction of plants; Origin of cultivated plants; Vavilov's centres of origin; Plants as sources for food, fodder, fibre, spices, beverages, edible oils, drugs, narcotics, insecticides, timber, gums, resins and dyes, latex, cellulose, starch and its products; Perfumery; Importance of Ethnobotany in Indian context; Energy plantations; Botanical Gardens and Herbaria.

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Domestication of plants

Introduction: What is domestication?

Domestication is a sustained multi-generational relationship between two species. In this, the dominant species controls the reproduction and takes care of another group to secure a more predictable supply of resources from that second group.

To be considered domesticated, a population of plants must have their behaviour, life cycle, or appearance significantly altered as a result of being under humans control for multiple generations.

Plant and animal domestication is the most important development in the past 13,000 years of human history. It is crucially important for all of us, scientists and non-scientists alike, because it provides most of our food today. It was also the prerequisite to the rise of civilization, and it transformed global demography.

Beginning of plant domestication

The earliest human attempts at plant domestication occurred in South-Western Asia. There is early evidence for conscious cultivation and trait selection of plants by pre-Neolithic groups in Syria: grains of rye with domestic traits have been recovered from Epi-Palaeolithic (c. 11,050 BCE) contexts at Abu Hureyra in Syria.

By 10,000 BCE the bottle gourd (*Lagenaria siceraria*) plant, used as a container before the advent of ceramic technology, appears to have been domesticated.

Cereal crops were first domesticated around 9000 BCE in the Fertile Crescent in the Middle East. The first domesticated crops were generally annuals with large seeds or fruits. These included pulses such as peas and grains such as wheat. The Middle East was especially suited to these species; the dry-summer climate was conducive to the evolution of large-seeded annual plants, and the variety of elevations led to a great variety of species.

As domestication took place humans began to move from a hunter-gatherer society to a settled agricultural society. This change eventually led to the first city states and eventually the rise of civilization itself.

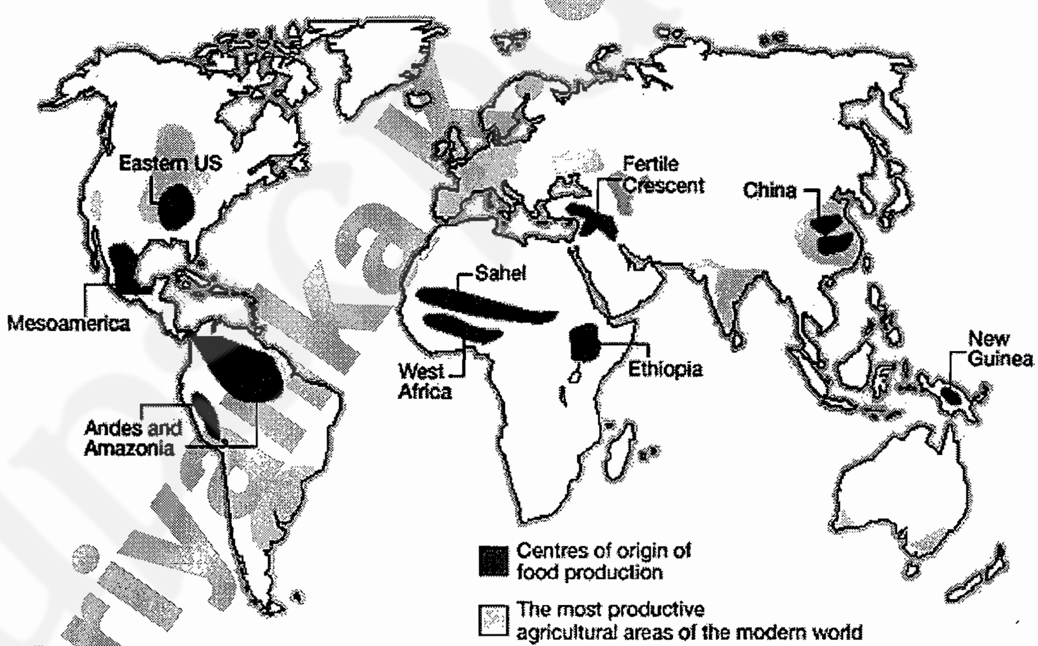
In other parts of the world very different species were domesticated. In the Americas squash, maize, beans, and manioc (also known as cassava) formed the core of the diet. In East Asia millet, rice, and soy were the most important crops.

Ancient and modern centres of agriculture

Ancient centres of origin of plant and animal domestication — the nine homelands of food production — are indicated by the dark-shaded areas on the map below. The most agriculturally productive areas of the modern world, as judged by cereals and major staples, are indicated by the light-shaded areas.

Note that there is almost no overlap between the areas highlighted, except that China appears on both distributions, and that the most productive areas of the central United States today approach areas of the eastern United States where domestication originated.

The reason why the two distributions are so different is that agriculture arose in areas to which the wild ancestors of the most valuable domesticable crops and animals were native, but other areas proved much more productive when those valuable domesticates reached them.



Genetic uniqueness associated with domestication

There is a genetic difference between domestic and wild populations.

Charles Darwin for the first time recognized the small number of traits that made domestic species different from their wild ancestors. He was also the first to recognize the difference between conscious selective breeding in which humans directly select for desirable traits, and unconscious selection where traits evolve as a by-product of natural selection or from selection on other traits.

There is also such a difference between the domestication variety and wild ones which have been essential at the early stages of domestication. Domestication traits are generally fixed within all domesticates, and they were selected during the initial episode of domestication.

The domestication of wheat provides an example. Wild wheat falls to the ground to reseed itself when ripe, but domesticated wheat stays on the stem for easier harvesting. There is evidence that this change was possible because of a random mutation that happened in the wild populations at the beginning of wheat's cultivation. Wheat with this mutation was harvested more frequently and became the seed for the next crop. Therefore, without realizing, early farmers selected for this mutation, which may otherwise have died out. The result is domesticated wheat, which relies on farmers for its own reproduction and dissemination.

Improvement traits in the domesticates were brought about by breeding exercise and they are present only in a proportion of domesticates.

The spread of food production

From the homelands of domestication, food production spread around the world in either of two ways. The less common way was for hunter–gatherers outside the homelands to acquire crops or livestock from the homelands, enabling them to settle down as farmers or herders. The clearest such example of local adoption of food production is in southern Africa, where around 2,000 years ago some Khoisan hunter–gatherers acquired Eurasian livestock (cattle, sheep and goats) arriving from the north and became herders (so-called Hottentots).

Much more often, however, local hunter–gatherers had no opportunity to acquire crops and livestock before they were overrun or replaced by farmers expanding out of the

homelands, exploiting their demographic, technological, political and military advantages over the hunter–gatherers.

Expansions of crops, livestock, and even people and technologies tended to occur more rapidly along east–west axes than along north–south axes.

The reason is: locations at the same latitude share identical day-lengths and seasonalities, often share similar climates, habitats and diseases, and hence require less evolutionary change or adaptation of domesticates, technologies and cultures than do locations at different latitudes. Examples include the rapid westwards and eastwards dispersal of wheat, horses, wheels and writing of western Asian origin, and the westwards dispersal of chickens, citrus and peaches of Chinese origin.

Consequences for human societies

Beginning around 8500 BC, the transition from the hunter–gatherer lifestyle to food production enabled people to settle down next to their permanent gardens, orchards and pastures, instead of migrating to follow seasonal shifts in wild food supplies.

Food production was accompanied by a human population explosion that has continued unabated to this day, resulting from two separate factors. First, the sedentary lifestyle permitted shorter birth intervals. Nomadic hunter–gatherers had previously spaced out birth intervals at four years or more, because a mother shifting camp can carry only one infant or slow toddler. Second, plant and animal species that are edible to humans can be cultivated in much higher density in our gardens, orchards and pastures than in wild habitats.

Food production also led to an explosion of technology, because sedentary living permitted the accumulation of heavy technology (such as forges and printing presses) that nomadic hunter–gatherers could not carry, and because the storable food surpluses resulting from agriculture could be used to feed full-time craftspeople and inventors. By also feeding full-time kings, bureaucrats, nobles and soldiers, those food surpluses led to social stratification, political centralization and standing armies.

All of these overwhelming advantages are what enabled farmers eventually to displace hunter–gatherers

Introduction of plants

Plant introduction consists of taking a genotype or a group of genotypes of plants into new environments where they were not being grown before. Introduction may involve new varieties of a crop already grown in the area, wild relatives of the crop species or a totally new crop species. Mostly materials are introduced from other countries or continents. But movement of crop varieties from one environment into another within a country is also introduction.

Examples of recent introduction were tobacco, Potato, maize in Asia, Ridley variety of wheat from Australia to India (resistant to brown and black rust, and to loose smut with good yield and grain quality). Sometimes a suitable or desired line or strain of a crop has to be introduced e.g. **a mung (*Phaseolus aureus*) variety from China** was introduced in India, but the variety gave poor yield and dull coloured seeds but during ongoing selection one single plant was found having large and bright colour seeds, **Shining mung no. 1 variety** of Punjab is the descendant of this single plant. Similarly, in many cases introduced varieties have been used as parents in crosses and their gene utilised in future progenies e.g. four resistant varieties of linseed were brought to India from Australia and with suitable crosses rust resistant genes were transferred to the Indian rust susceptible varieties of linseed.

What is required is **planned introduction** and for this it is essential to have a knowledge and collection of diverse genotypes of a species that can be used as a source material for desirable gene or characters and this germplasm collection includes local as well as exotic strains of the crop plants and its related species, which is used to genetically improve the species.

Types of plant introduction

Based on the area of introduction, plant introduction can be of two types: **Intra-country** (Grapes in Haryana, Rice in Punjab and wheat in Bengal and rest of the non-wheat growing areas of North East) and **Inter-country** introduction (Major type viz. Maize, Potato).

Based on the activity with these plants, they can be two types: Primary and Secondary

Primary introduction: When the introduced variety is well adapted to new environment and do not require to be manipulated and is straightforwardly released for commercial

cultivation. This kind of introduction is less common in countries which have their own well developed crop improvement programme. For example introduction of semi dwarf variety of wheat varieties Sonara 64, Lerma Rojo, Semi dwarf rice varieties IR8, IR28, Taichung native 1 etc.

Secondary introduction: The original genotype of the variety to be introduced is altered and subjected to selection to isolate the better performing progenies from the rest or better still the superior progenies are further hybridized with local varieties to transfer one or few characters from this variety to the local ones. E.g. Kalyan Sona and Sonalika wheat varieties developed from Mexican wheat genotypes.

Plant introduction for self and cross pollinated species serves the same purpose of increasing the options to improve a crop species or to simply broaden up the genetic base of a cultivar.

Application of Plant Introduction

1. To increase food options, by providing new crop species or varieties thus increase food security, e.g. Potato, maize etc.
2. To directly introduce better yielding commercial hybrids or CVs for profitable production of crop by the farmers thus improving farmer's condition.
3. Utilisation of introduced close relatives of an existing species into the crop improvement breeding programmes. E.g. Pusa ruby tomato was derived from a cross between a local variety (merruty) with Sioux from USA
4. Plant introductions helps in disease and pest management as sometimes a crop introduced into a new areas helps in the escaping from its natural predators and also in a new environment it has no natural enemies if that variety or species has not been growing there previously, e.g. Coffee was introduced in South America from Africa to protect it from leaf rust and Hevea was brought to Malaya from South America to protect it from a bacterial leaf disease.

Plant Introduction Agencies in India

A centralized plant introduction agency was initiated in 1946 at the Indian Agricultural Research Institute (IARI), New Delhi. The agency began as a plant introduction scheme in the Division of Botany and was funded by ICAR. In 1956, during the second five year plan,

the scheme was expanded as the Plant Introduction and Exploration Organisation. Subsequently in 1961, it was made an independent division in IARI, the Division of Plant Introduction. The division was re-organized as National Bureau of Plant Genetic Resources (NBPGR) in 1976. The nature of activities and the functions of the bureau have remained the same, but the scope and scale of its activities have increased considerably. The bureau is responsible for the introduction and maintenance of germplasm of agricultural and horticultural plants. In addition to the National Bureau of Plant Genetic Resources, there are some other agencies concerned with plant introduction. Forest Research Institute, Dehradun, has a plant introduction organization which looks after the introduction, maintenance and testing of germplasm of forest trees. The Botanical Survey of India was established in 1890; it was responsible for the introduction, testing and maintenance of plant materials of botanical and medicinal interest. But at present, introduction and improvement of medicinal plants is being looked after by NBPGR. The Central Research Institute for various crops, e.g., tea, coffee, sugarcane, potato, Tobacco, rice etc., introduce, test and maintain plant materials of their interest. But their activities are coordinated by the NBPGR, which has the ultimate responsibility for introduction activities. Plant material may also be introduced by individual scientists, universities and other research organizations. But all the introductions in India must be routed through the NBPGR, New Delhi.

The National Bureau of Plant Genetic Resources has its headquarters at IARI, New Delhi. It has four substations for the testing of introduced plant materials. These substations represent the various climatic zones of India which are most suitable to respective crop material, they are as follows:

1. **Simla, Himachal Pradesh**. It is situated in Himachal Pradesh and represents the temperate zone; approximately 2,300 m above sea level.
2. **Jodhpur, Rajasthan**. It represents the arid zone.
3. **Kanya Kumari, Tamil Nadu**. It represents the tropical zone
4. **Akola, Maharashtra**. It represents the mixed climatic zone. It was recently shifted from Amravati.

In addition, a new substation has recently been established at Shillong for collection of germplasm from North-east India. This part of the country has a large genetic variability for several crop species, e.g., rice, citrus, Maize etc. The bureau functions as the central agency for the export and introduction of germplasm of economic importance. The bureau is assisted in its activities by the various Central Research Institutes of ICAR.

The activities of the bureau are summarized below.

1. It introduces the required germplasm from its counterparts or other agencies in other countries.
2. It arranges explorations inside and outside the country to collect valuable germplasm.
3. It is responsible for the inspection and quarantine of all the introduced plant materials.
4. Testing, multiplication and maintenance of germplasm obtained through various sources. This may be done by the bureau itself at one of its substations or by one of the concerned Central Institutes of ICAR.
5. To supply, on request, germplasm to various scientists or institutions. The germplasm may be supplied ex-stock or may be procured from outside in case it is not available in the country.
6. Maintenance of records of plant name, variety name, propagating material, special characteristics, source, date and other relevant information about the materials received.
7. To supply germplasm to its counterparts or other agencies in other countries.
8. To publish its exchange and collection lists. An Introduction News Letter containing such lists is being published by the Food and Agriculture Organisation (FAO) since 1957 at irregular intervals. NBPGR has also published some lists, and is in the process of publishing some other catalogues.
9. To set up natural gene sanctuaries of plants where genetic resources are endangered.
10. Improvement of certain plants like medicinal and aromatic plants.

Procedure of Plant Introduction

Introduction consists of the following steps: Procurement, quarantine, cataloguing, evaluation, multiplication and distribution.

1. **Procurement**: Any individual or institution can introduce germplasm in India. But all the introductions must be routed through the NBPGR, New Delhi. There are two routes for plant introduction. In the first route the individual or the institution makes a direct request to an individual or institution abroad, which has the desired germplasm, to send it through the NBPGR, New Delhi. In second

procedure the individual or institute submits his germplasm requirements to the NBPGR with a request for their import.

2. **Quarantine:** Quarantine means to keep materials in isolation to prevent the spread of diseases to a new area where there has been no report of that disease or pathogen or pathotype whatsoever be the case may be. All the introduced plant propagules are thoroughly inspected for contamination with weeds, diseases and insect pests. Materials that are suspected to be contaminated are fumigated or are given other treatments to get rid of the contamination. If necessary, the materials are grown in isolation for observation of diseases, insect pests and weeds. The entire process is known as quarantine and the rules prescribing them are known as quarantine rules.

3. **Cataloguing:** When an introduction is received, it is given an entry number. Further, information regarding name of the species, variety, place of origin, adaptation and its various characteristics are recorded. The plant materials are classified into three groups.

   a. Exotic collections are given the prefix 'EC'

   b. Indigenous collections are designated as 'IC' and

   c. Indigenous wild collections are marked as 'IW'.

4. **Evaluation:** To assess the potential of new introductions, their performance is evaluated at different substations of the Bureau. In case of those crops for which Central Research Institutes are functioning, e.g., rice, sugarcane, potato, Tobacco etc., the introduced materials are evaluated and maintained by these institutes. The resistance to diseases and pests is evaluated under environments favouring heavy attacks by them.

5. **Multiplication and Distribution**: Promising introductions or selections from the introductions may be increased and released as varieties after the necessary trials. most of the introductions, however, are characterized for desirable traits and are maintained for future use. Such materials are used in crossing programmes and are readily supplied by the bureauon request.

Purpose of Plant Introduction

The main purpose of plant introduction is to improve the plant wealth of the country.

The chief objectives of plant introduction may be grouped as follows:

1. **To obtain an entirely new crop plant**: e.g., Maize, potato, tomato, Tobacco, etc., are introductions. Some recently introduced crops are Soybean, Cauliflower and Cabbage, Broccoli, Brussels Sprout, oil palm etc.
2. **To serve as new varieties which are directly released as superior commercial varieties**: e.g. Mexican semi dwarf wheat varieties Sonora 64 and Lerma Rojo, semidrawf rice varieties TN 1, IR-8 and IR-36 are more recent examples of this type.
3. **To be used in crop improvement by hybridization with existing cultivars**: e.g. Pusa Ruby tomato was derived from across between Meeruty and Sioux, an introduction from U.S.A. Another example is all the semi dwarf wheat varieties are derived from crosses with Mexican semi-dwarf wheat. Semi dwarf rice varieties possess the dwarfing gene from Dee-geo-woo-gen through either TN1 or IR8. Thus almost all these semi-dwarf wheat and rice varieties have been developed from crosses involving introductions. All the sugarcane varieties have been derived from the introduced noble canes. Pusa Early Dwarf Tomato derived from the cross Meeruti x Red Cloud; Pusa Kesar carrot, Pusa Kanchan turnip etc.
4. **To save the crop from diseases and pests**: e.g. Coffee was introduced in South America from Africa to prevent losses from leaf rust. *Hevea* (Rubber) was brought to Malaya from South America to protect it from a leaf disease.
5. **Collections of plants have been used for studies on biosystematics, evolution and origin of plant species.** N. I. Vavilov developed the concept of centres of origin and that of homologous series in variation from the study of a vast collection of plant types.
6. **For Aesthetic Value.** Ornamentals, shrubs and lawn grasses are introduced to satisfy the finer sensibilities of man. These plants are used for decoration and are of great value in social life.
7. **Varieties Selected from Introductions**: many varieties have been developed through selection from introductions. Two varieties of wheat, Kalyan Sona and Sonalika, were selected from introductions from CIMMYT, Mexico.

Merits of Plant Introduction

1. It provides entirely new crop plants.
2. It provides superior varieties either directly or after selection & hybridization.
3. Introduction and exploration are the only feasible means of collecting germplasm and to protect variability from genetic erosion.
4. It is very quick & economical method of crop improvement, particularly when the introductions are released as varieties either directly or after a simple selection.
5. Plants may be introduced in new disease free areas to protect them from damage, e.g., coffee and rubber.

Demerits of Plant introduction as witnessed in recent past

1. Many introduced plants bring with them, a number of weed species, diseases and pests. This happens due to similarity in seed size, shape and colour with the seeds of plant to be introduced, e.g. *Argemone Mexicana* and *Parthenium* were brought along with cereal crops etc.
2. Sometimes these alien species which are introduced become invasive species or in other words become weeds e.g. *Lantana camara* bought in for its ornamental value.
3. Threat to ecological balance due to encroachment of habitats with aliens.
4. No guarantee of whether the introduced plant will become a success and cater to the need of growing population.

Origin of cultivated plants and Vavilov's centres of origin

Origin of cultivated plants

Cultivated plant means plants that have been domesticated by man for economic use including for food, energy, etc.

The earliest evidence of genuinely cultivated forms so far discovered, dates from about 7000 B.C. in both hemispheres, i.e. some 10,000 years ago.

Early domestications were made more or less concurrently or independently on the lower slopes of the Zagros mountains and the 'fertile crescent' of the Tigris and Euphrates valleys in northern Iraq (Old World), and in the Tehuacan Valley of Mexico (New World).

Early man was a plant breeder, without any knowledge of genetics, displayed a noteworthy wisdom in domesticating plants and preparing them for food. Every important species of plant which we value today is a living tribute to our prehistoric ancestors who, long before the dawn of recorded history, discovered the virtues of certain plants, selected the most useful wild species and profoundly altered them some to the extent that their wild ancestors can't be traced.

For the discovery of many of these economic plants, their migrations from one continent to another, and knowledge of their properties and cultivation, we are indebted to the scholars of antiquity, the ancient conquerors, the medieval merchant princes, the Spanish conquistadores and the mariners and explorers of many lands. They all took with them seeds of their native plants and in return, brought home for transplantation whatever they found fit.

The real foundation of the scientific study of plants was laid by Greek and Roman physician-botanists such as Theophrastus ('the father of Botany'), Dioscorides, Pliny the Elder, Galen and others. Dioscorides' *De Materia Medica* is perhaps the most important of these ancient writings.

Darwin (1868) considered that the cultivated plants arose by profound modifications in the wild plants under cultivation.

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Mendel's work (recognised in 1900) formulated the laws of inheritance and attributed the origin of cultivated plants to natural selection and hybridisation.

In his *Origin of Cultivated Plants*, Alphonse de Candolle (1883) studied 247 species of cultivated plants and attempted to solve the mystery about the ancestral form, region of domestication and history of most of our important cultivated plants. In determining the place of origin of cultivated plants, he attached great importance to the presence of wild relatives.

He classified the economic plants into 6 classes organised into 2 principal groups–

Plants of old world origin

1. cultivated for at least 4000 years. Egs – almond, fig, peach, eggplant, etc.
2. cultivated for at least 2000 years. Egs – alfalfa, carrot, raddish, cotton, etc.
3. Plants cultivated for less than 2000 years. Egs – artichoke, okra, coffee, strawberry, etc.

Plants of new world origin

4. cultivated certainly over 2000 years and probably more than 4000 years. Egs – maize, tobacco, sweet potato, etc.
5. cultivated before the time of Columbus, but whose antiquity is not known. Egs – pineapple, tomato, guava, etc.
6. cultivated since the time of Columbus. Egs – blackberry, cinchona, plum, rubber etc.

He pointed out that cultivated plants originated sometime in the remote past from wild ancestors in rather restricted areas of the world with no communication with each other. These are : China, southwest Asia, including Egypt and intertropical America.

He believed in a single region of origin of crops.

N.I.Vavilov suggested 8 main geographic centres for cultivated plants. Zhuovsky, in attempting to better the idea put forward by Vavilov, suggested his concept of 'megagene centres' where species were domesticated. Also, he gave 'microgene centres' of wild species genetically related to cultivated plants. Harlan criticised the gene centre theory putting forward his idea of centres (places of agricultural origin) and non-centres (where agriculture has been introduced).

Vavilov's work

Nikolai Ivanovich Vavilov was a prominent Russian botanist and geneticist best known for having identified the centres of origin of cultivated plants. He devoted his life to the study and improvement of wheat, corn, and other cereal crops that sustain the global population.

N. I. Vavilov first published his concept of centres of origin of cultivated plants in 1926. It has profoundly influenced the thinking about the origins and spread of agriculture by b0tanists, geographers, anthropologists and archaeologists.

Vavilov, after a great deal of study, found that although many crops are grown all over the world, they actually originated at one or few place.

He determined 8 centres of origin of domesticated crops

He believed that the varieties grown in the centres of origin usually contained a large number of dominant genes with recessive gene never showing up due to nearly complete adaptation of the variety to its native site. However, the same crop in different environmental conditions showed new phenotypic characters due to changes in environmental condition leading to mutation in recessive gene making then important in new isolated regions.

His important finding can be concluded as follows:

1. 85% of 640 crop species are in old world.
2. There are small areas in tropics and subtropics which are endowed with greatest wealth of forms, gene or diversity centres and from these centres the species have migrated in different direction in the course of which they have shown adaptive changes and these accumulation of variation led to formation of cultivars
3. Primary crops have multiple origins viz. Wheat, Rice, potato, Soybean, Flax, Cotton.
4. When primary crops along with forage crop or weed were taken from one place to another very distant place beyond many climatic zones, the forage became the primary and primary became weed or forage due to radical changes in the environmental conditions, thus gradually primary crops and associated crops are said

to have multiple origins as they are found with many different civilization as part of their cultural and ethnic diet.

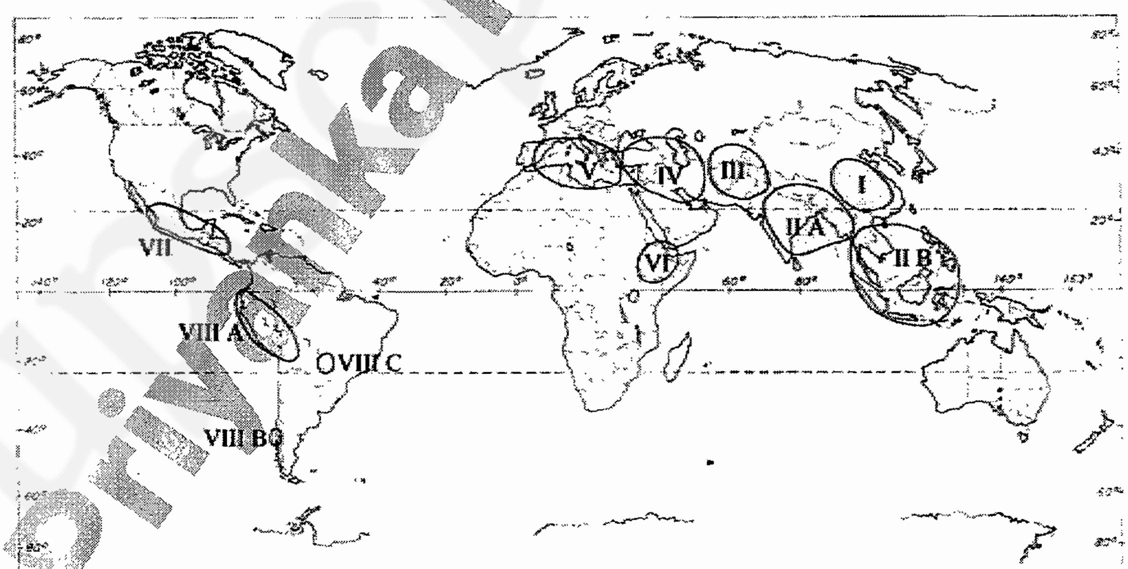
5. Genetic diversity within a species at its centre of origin may or may not be very high. There are cases when higher genetic diversity is more in secondary centres e.g. maize and tomato

6. He proposed primary and secondary centres of origin.

    a. **Primary centre** are those which are characterized by dominant gene expression with maximum number of wild relative present nearby. It was their cultivation since ancient times that has led to diversity in that species, if any so basically longer periods of perpetuation of a number of crop species is important here.

    b. **Secondary centre** or accumulation gene centres formed due to human migration patterns over long distances across physical barriers. Secondary centres are characterized by recessive allele expression that is neo types are common here. There are no wild relatives even in 1000 km radius. It was natural forces that led to the diversity. So, ecological diversity, farming practice, human migration patterns towards different races of a crop are important here.

The Centres of Origin as Proposed by N.I Vavilov (1926, 1935)



Vavilov considered that "as a rule the primary foci of crop origins were in mountainous regions, characterized by the presence of dominant alleles." In his work entitled The Phytogeographical Basis for Plant Breeding (Vavilov 1935), he summarizes and pulls together all his previous work on Cenres of origin and diversity. In this he recognizes eight primary Cenres, as follows.

I. **The Chinese Centre**- in which he recognizes 138 distinct species of which probably the earlier and most important were cereals, buckwheats and legumes.

II. **The Indian Centre**

IIA. Including the southern subcontinent - based originally on rice, millets and legumes, with a total of 117 species.

IIB. The Indo-Malayan Centre (including Indonesia, Philippines, etc.) - with root crops (Dioscorea spp., Tacca, etc.) preponderant, also with fruit crops, sugarcane, spices, etc., some 55 species.

III. **The Inner Asiatic Centre** (Tajikistan, Uzbekistan, etc.) - with wheats, rye and many herbaceous legumes, as well as seed-sown root crops and fruits, some 42 species.

IV. **Asia Minor** (including Transcaucasia, Iran and Turkmenistan) - with more wheats, rye, oats, seed and forage legumes, fruits, etc., some 83 species.

V. **The Mediterranean Centre**- of more limited importance than the others to the east, but including wheats, barleys, forage plants, vegetables and fruits - especially also spices and ethereal oil plants, some 84 species.

VI. **The Abyssinian (now Ethiopian) Centre**- of lesser importance, mostly a refuge of crops from other regions, especially wheats and barleys, local grains, spices, etc., some 38 species.

VII. **The South Mexican and Central American Centre**- important for maize, Phaseolus and Cucurbitaceous species, with spices, fruits and fibre plants, some 49 species.

VIII. **South America**

VIIIa. Andes region (Bolivia, Peru, Ecuador) - important for potatoes, other root crops, grain crops of the Andes, vegetables, spices and fruits, as well as drugs (cocaine, quinine, tobacco, etc.), some 45 species.

VIIIb. The Chilean Centre- only four species - outside the main area of crop domestication, and one of these (Solarium tuberosum) derived from

the Andean Centrein any case. This could hardly be compared with the eight main Cenres.

VIIIc. Brazilian-Paraguayan Centre- again outside the main Cenres with only 13 species, though Manihot (cassava) and Arachis (peanut) are of considerable importance; others such as pineapple, Hevea rubber, Theobroma cacao were probably domesticated much later.

Importance of ethnobotany in Indian context

Ethnobotany is the study of the human conceptualisation and use of plants historically and cross-culturally.

The term "Ethnobotany" - derived from two Greek syllables - *Othnikos* or *ethnos*, means nation or race, and *botanikos* or *botane*, meaning plant. Etymologically, it refers to the study of plants by races.

The term was first coined by Dr. John W. Harshberger (1895).

The relationship between the indigenous people and their plant surroundings forms the subject of Ethnobotany.

Ethnographers describe the people of a region including their race, language, and their uses of plants:

- Food and its methods of preparations
- Medicine
- Extraction of fatty oils
- Edibles and non-edibles
- Condiments and spices
- Seasoning material

Ethnobotany in India

Ethnobotany is not new to India, Kirtikar and Basu (1935) stated, "The ancient Hindus should be given the credit for cultivating what is now called ethnobotany".

India has about 563 tribal communities having age-old traditional knowledge through their long association with the forests. They have accumulated valuable knowledge on the use of wild plants in their daily life for food, fuel, fodder, clothing, health-care and other purposes.

Archaeological resources

India has a rich treasure of archaeological sculptures of antiquity, which can be of great value in tracing the plants which were used during early civilization.

Sithole (1976) described about 40 such plants from bas reliefs on the gateways of the Great Stupa at Sanchi and the railing of Bharhut tupa, belonging to the first and second century B.C., respectively.

Literature resources

Our ancient literature can also be tapped for information on medicinal plants.

Rigveda and Atharvaveda, which date back to 2000 to 1000 B.C. which are our oldest Vedic literature resources, contain valuable information regarding medicinal plants of that period.

Sharma (1968-69) enlisted 248 botanical drugs which are mentioned mainly in Atharvaveda and Rigveda. Singh and Chunekar (1972) published a glossary of such medicinal plants, which have been mentioned in Charak Samhita, Sushurta Samhita and Ashtanga Hridiyam.

Perhaps the outstanding example, at least in modern times of the use of the literature is the huge compilation of all anti-tumour plants, cited in old texts and local folk medicine from all over the world for screening purpose at Cancer Chemotherapy National Service Center (CCNSC) (Hartwell, 1967-71).

Recently, checklists of Ayurvedic and Yunani treatises have been published.

Herbarium Resources

Herbarium sheets and field notes have also proved to be a good source of ethnobotanical data. The most outstanding example of this type of research is of Dr. Altschul, who searched about 2.5 million plant specimens in Harvard University Herbarium and from these 5,178 useful notes of drugs and food value were recorded (Altschul, 1973).

Field Resources

The plants have become the never ending source for new biodynamic compounds of potential therapeutic value. Ethnobotanist brings out from the field the suggestion as to which raw plant material may be tapped and for this, he gets clues from the tribals.

Atkinson (1882) published 12 volumes of the Gazetteer of North West Provinces of India, three of which are concerned with the Kumaon and Garhwal Himalayan Region. Recently,

the Central Councils for Research in Ayurveda, Siddha and Yunani conducted several medico-botanical surveys in some important ethnic and tribal regions of the country.

It was found that the Nicobaris use the resinous wood of *Canarium* and *Dipterocarpus* spp. for repelling mosquitoes and as a torch.

In the Nilgiris, the decoction of *Bambusa arundinacea* is used as an abortifacient (Ragunathan, 1976).

Wild medicinal plants in Indian folk life

Pats of over 3500 wild species are used to cure ailments in man and his domesticated animals:

1. For wounds and as disinfectant. *Panicum anidotale*, *Artemisia maritima*
2. Bronchial troubles. Bulbs of *Urginea indica*
3. Blood purification and promoting lochial discharge. *Mollugo cerviana*
4. Urinary troubles. *Glinus lotoides*
5. For swellings. Root paste of *Corallocarpus epigaeus*
6. As tonics. *Neurada procumbens* and *Colchium luteum*, seeds of *Mimosa hamata*, root of *Asparagus recemosus*
7. Pneumonia. *Achyranthus aspera*

Plants in folk medicine of the Himalaya

The Himalayan ranges are inhabited by a large tribal population, often with their distinct way of life, traditions, dialects and cultural heritage. The Himalayas have bestowed them with vast, varied and even endemic plants.

The tribals have learnt to utilize local herbs for different ailments after centuries of trials.

Some folkore medicines of the region have proved efficaceous after detailed pharmacological and clinical trials. *Rauvolfia serpentina* roots are a classical example. *Coptis teeta* is another plant which has given encouraging results. The oil of seed kernel of *Hydnocarpus kurzii*, from upper Assam and Tripura hills, has proved useful in the treatment of leprosy and skin diseases. The roots of *Nardostachys grandiflore* have provided a safe sedative.

Use of plants in folk medicine by tribals of Central India

Use of plants in folk medicine is very prevalent in Central India. More than one hundred plants were reported to be commonly used in medicine in the district of Bastar. Some plants are used singly, whereas others are used in mixture. Similarly, certain plants were considered useful in only one disease whereas several had multiple uses.

Examples of a few such plants are given below:

- *Cassia tora* (Charota): Tender leaves eaten to prevent skin diseases.
- *Combretum decandrum* (Ainti): Oil from seeds applied on eczema.
- *Flacourtia indica* (Kakai): Bark applied on eczema.
- *Nyctanthes arbortristis* (Harsingar): The inflorescence and young fruits pounded in water; this is used for relieving cough.
- *Polygonum plebejum* (Chatibhaji): The plant eaten as a vegetable to promote lactation.

The Botanical Survey of India (BSI)'s initiative

The Botanical Survey of India (BSI) was established in 1890 with the objectives of exploring the plant resources of the country and identifying plant species with economic virtue.

Botanical Survey of India initiated recording and documenting this ethnobotanical data of all tribes belonging to the states of Bihar, Goa, Karnataka, Orissa Rajasthan, Himachal Pradesh, Chattisgarh, Uttaranchal, Andaman and Nicobar Islands, Andhra Pradesh, Arunachal Pradesh, Assam, Jammu and Kashmir, Madhya Pradesh, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh and West Bengal for critical studies leading to sustainable utilisation of bioresources, documentations of traditional knowledge system.

Energy plantations

An overview of energy plantations

Technically speaking, energy plantation means growing select species of trees and shrubs which are harvestable in a comparably shorter time and are specifically meant for fuel.

The fuel wood may be used either directly in wood burning stoves and boilers or processed into methanol, ethanol and producer gas. These plantations help provide wood either for cooking in homes or for industrial use, so as to satisfy local energy needs in a decentralised manner. The energy plantations provide almost inexhaustible renewable sources (with total time constant of 3-8 years only for each cycle) of energy which are essentially local and independent of unreliable and finite sources of fuel. The attractive features of energy plantations are: (a) heat content of wood is similar to that of Indian coal, (b) wood is low in sulphur and not likely to pollute the atmosphere, (c) ash from burnt wood is a valuable fertiliser, (d) utilisation of erosion prone land for raising these plantations helps to reduce wind and water erosion, thereby minimising hazards from floods, siltation, and loss of nitrogen and minerals from soil and (e) help in rural employment generation - it is estimated that an hectare of energy plantation is estimated to provide employment for at least seven persons regularly. Selection of multipurpose species provides a number of by-products like oils, organic compounds, fruits, edible leaves, forage for livestock , etc .

Why are they needed?

Fuel is one of mankind's primary necessities. With the depletion of fossil fuel reserves on one side and their ever increasing demand for our expanding industries and urbanization and thirdly the threat of global warming through rising levels of green house gas emissions, the world is searching for viable alternative energy sources. Energy crops or bio crops or plantation crops are one such option that is renewable, clean, and affordable with increasing technological advancements.

A few examples of conventional energy crops providing biofuels

A large number of xeric plants belonging to Euphorbiaceae, Asclepiadadeae, Asteraceae and several other families synthesize in their tissues hydrocarbons or crude oils.

Of particular interest are species such as *Guayule*, *Euphorbia* spp., *Calotropis*, *Jojoba* (*Simmondsia chinensis*), *Pedilanthus* and *Cryptostegia*, *Copiaba*, Petroleum nut that naturally produce organic material in a highly reduced state for the production of pure hydrocarbons. Among the lower plants, *Botryococcus*, a colonial alga, is a promising source of hydrocarbon.

- **Guayule** – (1) a bushy, silver-grey plant of Asteraceae, (2) native to Sonoran desert of Mexico and parts of semiarid southwestern US, (3) contains 25% rubber hydrocarbons, mainly in stem and branches and little in roots, (4) latex contains hydrocarbons of high molecular weight, (5) In India, grown in arid regions of Maharashtra, Rajasthan and Gujarat.
- **Euphorbias** – (1) around 2000 Euphorbia spp. In the world, (2) mostly native of Africa, capable of growing under semi-arid conditions, (3) *E.lathyrus* latex contains high percentage of hydrocarbon like materials – worked upon by Melvin E. Calvin of the Calvin cycle who studied terpenoid biosynthesis in it to be used for energy production.
- **Botryococcus** – (1) colonial green alga, (2) occurs in fresh water lakes and brackish water across all continents, (3) hydrocarbon content o a dry weight basis is around 20% during the exponential growth phase but about 80% in the resting stage.

Governments' policy worldwide

3 countries with major biofuel programmes – Brazil (sugarcane and Casava), USA (corn, grain and sorghum), and Zimbabwe.

Besides, many developing countries including India have embarked upon an ambitious biofuel programme.

Brazil is an unquestioned leader and petrol sold in Brazil contains 20% alcohol (gasohol). The Americans have a gasohol programme which blends gasoline with 10% alcohol, driven from corn.

Indian Policy

The Ministry of New & Renewable Energy has proposed a national biofuels policy with a target of 20% blending of transportation fuels — diesel and petrol (gasoline) — with bio-

diesel and bio-ethanol by 2017. While a blending target for bio-ethanol has been in effect since 2008, a fresh recommendation has been issued for bio-diesel.

The Government proposes to encourage farmers and landless labourers to plant non-edible oil seeds to boost the production of bio-diesel and bio-ethanol. The agricultural produce shall be procured by public or private processing entities through the Minimum Support Price mechanism.

The Government looks to solve several problems in the environment, agriculture, and economic domain. Apart from curbing air pollution from the transportation sector, the Government plans to increase employment opportunities for farmers, especially the ones with little financial means. A boost in bio-ethanol will be a lifeline for the desperate sugar industry.

To expedite the proliferation of bio-diesel and bio-ethanol across the country, the Government will enhance the incentives for processing and production activities. Foreign investment in the sector would also be encouraged.

The Motors Vehicles Act already allows "conversion of an existing engine of a vehicle to use biofuels." Engine manufacturers will be required to make the necessary changes to the engines to ensure compatibility with biofuels.

Jatropha and Karanj

The Planning Commission had earlier recommended 2 plant species – Jatropha (*Jatropha curcas*) and Karanj (*Pongamia pinnata*) for commercial biodiesel extraction. India already has 60,000 hectare under Jatropha plantations in Andhra Pradesh, Rajasthan, Madhya Pradesh and Chhattisgarh. It is contemplated to use biofuels not only for producing fuels but also for electrification. It is estimated that 12 million ha of land would have to be brought under biofuel crops by using only degraded, arid, semi-arid, forest wasteland.

Research on crop plants undergoing in CAZRI, Jodhpur, CSMCRI, Bhavnagar,IIT-D, IISc, Bangalore in India.

Challenges

Converting agricultural commodities such as sugarcane, sugarbeet, sweet sorghum, many major cereals, cassava and Jerusalem artichoke into alcohol may have serious consequences, particularly in the Third World Countries. Critics have cautioned that

agriculturally based ‘alcohol fuel’ production is not a wise venture. The issue is of food versus fuel as witnessed in soaring food prices worldwide due to production and supply deficiencies worldwide.

One way to minimize food-fuel completion is to identify wild or undomesticated plants with a high content of hydrocarbons of low molecular weight as alternative fuel sources.

Botanical Gardens

A botanical garden is a place where plants of different kinds and varieties, collected from various parts of the country and the world, are grown in a scientific and systematic manner. It functions as an institution of scientific activities, both pure and applied, and as a place of aesthetic value to bring awareness in general public about plants.

History – Ancient Indian history mentions about gardens such as 'Panchvati' and 'Ashok Vatika' in our great epic Ramayana. Many Indian rulers developed gardens for aesthetic beauty. The development of botanical gardens in western countries started as centres of cultural activities.

World's 1st botanic garden established by Luca Ghini in 1544, Italy – at Pisa.

Functions of Botanic Gardens

- Raising, introducing and acclimatising wide variety of global trees, shrubs, herbs and climbers of cultivated plants of economical value.
- Conducting explorations, floristic studies and research in plant taxonomy and other related disciplines.
- Supply of authentic plant material to organizations engaged in R&D.
- Provide aesthetic appeal and attract people to observe general plant diversity.
- Integration in research projects to incorporate information obtained from related branches such as anatomy, embryology, ecology etc., in plant taxonomy with the help of research labs.
- Ex-situ conservation of genetic diversity, as also conservation of rare and endangered plant species.
- Maintaining herbarium as a record of plants.
- Offering literature about plant taxonomy and other related fields by its library.
- Facilitate domestication and conservation of wild plant species of economic values.
- Provision of sale of plants, seeds or plant propagules to garden lovers.
- Offering seed exchange with those interested.
- Provision of technical advice/consultation service for improvement of other gardens.
- Networking of database of plant resources and to document and publish it.

- Organising conferences, seminars, popular lectures etc., to create mass awareness of plants.

A synopsis of two major Botanical gardens

Royal Botanic Gardens, Kew, England

- The finest and largest botanic garden in the world.
- Most important botanical research and resource centre in the world.
- Developed around 1600 by the Kew House owned by Richard Bennet.
- Sir William J. Hooker – its 1st official director.
- John Hutchinson developed his system of classification here.
- Hosts the largest herbarium in the world.
- Kew Herbarium has 275,000 Type specimens.
- The living collection of the garden at Kew and Wakehurst – largest and most diverse in the world – presents a multilevel encyclopaedic reference collection reflecting global phytodiversity.
- Diversity – 351 families, 5465 genera and more than 28,000 species – grown successively here.
- Other remarkable features of garden – Chelsea Physic Garden Demonstration, world's best Rock Garden famous for its Himalayan Alpine plants.
- *Kew Bulletin* and *Index Kewensis* – 2 continuing premier publications.
- Maintains database on plant names,taxonomic literature, economic botany, plants of arid lands and on plant groups of special economic and conservation values and makes about 10,000 identifications a year through its *Herbarium Service.*
- Involved in major phytodiversity programmes in many parts of the world.

The Indian Botanical Garden, Sibpur, Howrah, Kolkata

- One of the greatest botanic gardens in the world and one of the first to be established in the tropics.
- Largest and oldest botanic garden in India on the bank of Hooghly river.
- Founded by Lt. Col. Robert Kyd in 1787.
- William Roxburgh (Father of Indian Botany), N. Wallich, W. Griffith, David Prain and Dr. K Biswas (1st Indian appointed as Superindent of this garden) other workers worked here.
- Covers an area of 110 ha of land and contains representative collection of world with about 12,000 living plants, mostly of tropics.

- Main attraction – the great Banyan tree (*Ficus bengalhensis*) – 2 centuries old.
- Other interesting features – palm houses, the amazon lily (*Victoria amazonica*), Cocoa, Coffee, Cardamom, Chinchona, etc.
- Also has well-maintained Bambusatum, Orchid House, Pinetum, Cactus House, Fernery, etc.
- Maintained by Botanical Survey of India estd in 1890.
- It has the Central National Herbarium with rich collection of specimens over 2 million including more than 10,000 Type Specimens of Indian species of flowering plants.

Herbaria

Introduction to a herbarium

A herbarium is a collection of plant samples preserved for long-term study. These materials may include pressed and mounted plants, seeds, wood sections, pollen, microscope slides, frozen DNA extractions, and fluid-preserved flowers or fruits; all are generally referred to as herbarium specimens. Worldwide there are over 300 million specimens preserved for research in herbaria (plural for herbarium).

Herbaria are usually associated with universities, museums, or botanical gardens.

The first is believed to have been established in 1570 in Bologna, Italy, by Luca Ghini.

There are now around 4,000 herbaria in over 165 countries. A world catalog of public herbaria, **Index Herbariorum**, is published periodically by the International Association for Plant Taxonomy. Each herbarium in *Index Herbariorum* is assigned an official acronym (code) that is used as a standard for referring to the institution and its specimens.

Approximate list of the ten largest herbaria in the world:

Location	Name	Specimens in million
Paris, France	Muséum National d'Histoire Naturelle	9.5
New York, USA	New York Botanical Garden	7.2
St. Petersburg, Russia	Komarov Botanical Institute	7.2
London, England	Royal Botanic Gardens, Kew	7
Geneva, Switzerland	Conservatoire et Jardin botaniques de la Ville de Genève	6
St. Louis	Missouri Botanical Garden	5.9
The Netherlands	The Nationaal Herbarium Nederland (NHN)	5.5
London, England	British Museum of Natural History	5.2
Cambridge, Massachusetts	Harvard University Herbaria	5
Vienna, Austria	Naturhistorisches Museum Wien	5

Herbarium techniques

Collection – (1) Specimen should have flower and fruit, if present, (2) Herbs collected with roots or underground parts, (3) For Woody plants – twig with leaves and flowers.

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(b) Mounting of Specimen – (1)specimens after drying in the press should be pasted on the herbarium paper (standard size 11.5 by 16.5 inches).(2) Strobilus, cones and other parts which are not suitable for pressing may be bagged within plastic bags or paper packed pasted on mounting sheet.

↓

(c) Labelling – After mounting, a label is glued on the lower right hand corner of the sheet, to provide information gathered from field notebook.

↓

(d) Preservation of Specimens –(1) Healing, repellents (such as parachlorobenzene, naphthalene), fumigants (such as Ethylene dichloride with one part Carbon tetrachloride) used to check attack of destructive agents.

↓

(e) Plant Identification – Knowing the name of the family, turn to the section where it is treated & there, by means of the key to genera, repeat the procedure to determine its generic name. After this, and by use of the key to species, the specific identity of the unknown is learned.

Maintenance

- Like all museum collections, herbarium specimens are stored in perpetuity. The successful long-term storage of specimens necessitates specialized materials, procedures, and facilities. For example, mounting and label papers, folders, storage boxes, inks, and adhesives must all be archival. This means that they lack acids and other constituents that may cause the specimens to degrade over time.
- To further minimize degradation, specimens are stored in tightly sealed metal cabinets, which are periodically treated with an insecticidal fumigant.

- Maintaining a cool, dry storage environment helps reduce the risk of insect and fungal damage to specimens.
- All incoming plant materials, including both field collections and loans of mounted specimens, are frozen at -5° F for 7 days to kill pests.

Use of herbaria

Herbarium specimens are useful as references for plant identification and for the determination of plant locations and ranges, abundance, habitat, and flowering and fruiting periods. They are used for studies in which the differences between plant species are evaluated and described (monographs) or in which the species growing in a region are reported (floras).

Plant systematics is the core research emphasis for herbarium staff. There are four main areas in systematics --

1. taxonomy - the recognition and formal description of taxa (plant entities);
2. nomenclature - the formal naming of taxa;
3. phylogeny - the analysis of taxon relationships; and,
4. classification - the formalized hierarchical arrangement of taxa into groups.

The results of systematic research help us to better understand plant identities and relationships.

Herbarium specimens are also useful in many other disciplines. Examples of other uses include:

- Agronomy/Forestry - locate wild plants that have potential as new crops; document plants used as crops and forage; locate and identify relatives of cultivated species for use in breeding programs; identify and document the spread of weeds
- Anthropology/Archeology - identify seed, wood and other plant remains from archeological sites; document plants used by people (ethnobotany)
- Ecology - locate and document plant communities or individual species; identify and document invasive species
- Entomology - locate food plants and habitats for insects; document pollination ecology

- Environmental Regulation – identify plants in an area in order to define the habitat and designate an environmentally and legally appropriate use for the site
- Forensics – identify plant fragments that might yield evidence in legal cases; in some cases plant fragments may be used to determine if a person was in a certain place
- History – retrace itineraries of early naturalists; track down early place names; determine historic plant ranges
- Horticulture – identify native and cultivated plants; find plant locations; document cultivars
- Pharmaceutical Research – locate wild plants as possible source of medicines
- Poison Control and Medical Care – identify plants in cases of ingestion
- Veterinary Science – identify forage and poisonous plants
- Zoology – identify animal food plants; locate animal habitats

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